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Ukraine
Dispatch and System Control

FINAL REPORT

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[Submitted For Inclusion In the Body of the Aide - Memoire As Paragraphs 9 and 10.]

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D. DISPATCH AND SYSTEM CONTROL

Executive Summary

9. Current Status:

The goals of this study are:

(i) to facilitate effective operation of the future power system under the newly re-structured electric power sector; and,

(ii) to identify necessary upgrades of equipment and procedures so that Ukraine may be re-connected with its neighboring utilities.

Obstacles to effective operating of the new power system are the interconnection and customer metering among all of the enterprises (member companies and large customers), and a method to collect each day the bid and forecasts from the various new generating companies and large customers. Obstacles to reconnecting to neighboring utilities are: 1) inability of the load - frequency control (LFC) system, particularly the control equipment at the power plants, to maintain frequency and time within acceptable limits, 2) availability of enough of the right fuel (both quality and consistency) to keep the generators running, and 3) automatic control of power flows on interconnection lines.

10. Proposed Upgrade Measures.

Six projects have been identified to solve the problems described above.

1. Restoration of LFC and associated equipment at hydro plants;
2. Restoration of LFC and associated equipment at thermal plants;
3. Data acquisition and control equipment between plants and the National Dispatch Center;
4. Data presentation and routing computers for the eight (8) Regional Dispatch Centers;
5. Monitoring inter-enterprise energy (MWH) exchanges at key sub-stations; and,
6. Implement LFC and On-Line Economic Dispatch by upgrading the computer system at the National Dispatch Center.

The estimated cost of these six projects is $ 19.56 million for the foreign exchange component, and $ 6.224 million for the local component. The estimated annual benefits are $ 39.3 million, and result from enabling the on-line economic dispatch of the generating units. On-line economic dispatch minimizes the cost of fuel burned, while supplying the load, and managing the cost of fuel. It is estimated that with the rehabilitation of all of the hydro plant LFC equipment and about half (63 of 116 units) of the thermal plant equipment, the annual fuel cost savings will be about 1.9 percent. An annual fuel cost of $ 2.045 billion was used. The problem with the quality and consistency of coal is the subject of another study. The hydro rehabilitation project supports this project by restoring the governors of the hydro units; the estimated cost of this governor work is $10.270 million foreign exchange and $ 3.160 million local. Annex (2) provides supporting material for the above recommendation.

1 SCOPE AND PURPOSE

An assessment of the existing control, communications and dispatch system and methods was developed. Recommendations about necessary upgrades were identified to bring these functions to a level that would enable the following.

a. Facilitate effective operation of the future power system; and,

b. Re-integration of Ukraine's power system with the neighboring electric power systems.

2 BACKGROUND INFORMATION

Changes in the past few years have caused problems to appear in the Ukraine power system. This Section summarizes some of those changes. Also, general control of a power system is described. The problems are reported in Section 4, below.

2.1 Independence.

When Ukraine was part of Russia, the power system of Ukraine was designed and operated as an integral part of the whole Russian power system. Particularly, system frequency was regulated by the hydro generating plants on the Volga River.

With the independence of Ukraine, the generating plants on the Volga River remained with Russia. Then, in November, 1993, all interconnections between Ukraine and the neighboring countries were opened.

However, the physical boundary of Ukraine is not the same as the power system boundary. A portion of Bulgaria is tied to Ukraine; the rest of Bulgaria is connected to the Central European power system. A portion of eastern Ukraine is connected to and operated with the Russian power system. In exchange, the Russian North Caucasus region is connected to and operated by Ukraine. A portion of western Ukraine is connected to the Central European power system so that electricity can be exported to central Europe.

2.2 Restructuring of the Electric Power Sector.

Restructuring of electric power sector is planned to occur in the next few months. This restructuring will establish the following as separate corporations. (TBD - Quantity to be determined later; quantity not known at time report was published.)

Quantity	Description
17	Large thermal generating stations.
20-25	Smaller combined heat and power generating stations.
TBD	Industrial cogenerators that sell excess power to the power system.
5	Nuclear power stations.
8	Hydroelectric power stations.
1	High voltage transmission network.
27	Local electricity companies (LECs).
TBD	Large industrial customers.

Though there is watthour (energy) metering in the generation and transmission portion of the Ukrainian power system today, it is not extensive enough to meter all of the information needed to support the above new corporate structure. Furthermore, there is no communications equipment to collect the metering information every hour, as required by modern interconnected power system operation.

2.3 Maintenance of Equipment.

Economic and social changes of the past few years have resulted in less maintenance and equipment upgrades for dispatch and control than in the past. Nearly all of the control equipment at the power

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plants dates from original construction (usually 30 years ago). The computers, telemechanical equipment, and communications electronic equipment is correspondingly at the end of its useful life (most of it is at least 10 year old). The dispatch computers and data collection computers at the National Dispatch Center are 10 years old.

The personnel of the Ukraine power industry are doing an admirable job of keeping the equipment and the system operating.

2.4 Manufacturers of Equipment.

Many of the manufacturers of the control, communications, and computer equipment were Soviet companies, which no longer exist. There are no manufacturers from which to obtain spare parts, servicing, or upgrades.

In some cases, the manufacturers of equipment are now in foreign countries. For example, governors and circuit breakers are manufactured in St. Petersburg, Russia. Major disconnecting devices are made in Ekaterinburg, Russia. Purchases from these plants are now foreign trade for Ukraine, and are hard to obtain.

2.5 Control Of an Electric Power System.

Modern electric power systems are controlled by three major feedback control loops. Each loop includes the governor - regulators at the generating units. Each control loop serves a different purpose, and expects to use each kind (hydro, thermal and nuclear) generating unit differently.

The control loops recognize the particular strengths and limitations of each generating unit. Hydro units have fast response times (2 to 30 seconds), but their reservoirs can be drained quickly. Thermal plants generate large amounts of electricity, but their coal and ash handling systems, boilers, and turbines can change power output only very slowly (over many hours). Also, the operation of coal fired plants is severely limited by the quality and consistency of the coal, and the transport capacity (tons per hour) of the coal feed and ash handling equipment, and the boilers.

2.5.1 Primary Control.

Response times here are from about 2 to 30 seconds. Hydro units are the primary contributors to control in this loop because they can raise or lower their outputs by quick changes in wicket gate positions at the entrances to the turbines.

This control loop is responsible for maintaining about 50 Hertz when regulating by the speed mode of the governor.

2.5.2 Secondary Control.

Response times here are from about 1 minute to 5 minutes.

The hydro units, and that part of the thermal units that can respond within their regulating range, contribute to this control loop. This control loop senses, responds to, and controls the interconnection power flows.

This control loop is responsible for regulating frequency, for meeting the scheduled interconnection transactions, and for making temporary adjustments to system frequency (say, 50.05 Hertz) to reduce or eliminate any time error.

2.5.3 Tertiary Control.

Response times here are from about 10 minutes to 6 (or more) hours.

The larger thermal units contribute to this control loop by significantly moving their power out (for example, moving from 425 MW to 750 MW over a 6 hour period). Smaller thermal units contribute to this control loop by coming on or off standby mode. Hydro units contribute to this control loop by coming on or off line.

2.6 Design of Generating Units.

Under the Russian system, the power plants were designed for one mode of operation. Today the plants have to be operated in other modes. This is not good for power plant equipment and for system operations.

The hydro and thermal units were designed to be based loaded, with frequency and capacity regulation being handled elsewhere in Russia. Thermal plants were designed to burn coal of a set quality (heat content, expressed in units of kilocalories per kilogram of coal; and ash content, expressed in units of percent).

Most importantly, the overall quality of the coal shipment was expected to be consistent and predictable.

2.7 Import of Gas and Mazut.

Before independence, natural gas and mazut (fuel oil) came from Russia as a local commodity. Now the gas and mazut must be imported from Russia and paid for with hard currency. Now the use of gas and mazut fired power plants is minimized. Thus, many of the larger generating units (which are fired with gas or mazut) are not in service, and additional demands are placed upon the smaller coal fired units to follow load.

3 SITE VISITS

In addition to discussions with the staff of the National Dispatch Center, and the hydro and thermal plant departments of the Ministry of Power and Electrification of Ukraine (Minenergo), visits to the following facilities were conducted.

Dneprovskaya Hydro No. 1 and 2;
Dneproznergo;
Kiev Hydro;
Kremenchug Hydro; and,
Zaporozhye steam central power plant.

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4 TECHNICAL FINDINGS

4.1 Regulation of Frequency.

Frequency is regulated to stay within the band 49.5 to 50.2 Hertz. The target frequency is 50.0 Hertz. At times the frequency exceeds the band.

Frequency is controlled manually from the Dneprovskaya Hydro No. 1. Dneprovskaya Hydro No. 1 (650.6 MW) and Kremenchug Hydro (625 MW) are the only generating plant in the Ukraine power system that are regulating frequency. The installed capacity at these two plants is 1,275.6 MW, of which 1,100 MW is available to participate in LFC.

The National Dispatch Center plans to have 6,400 MW of generation on line to regulate frequency. Table 4.1.a on page 11 shows where the increased capacity participating in LFC is expected to come from.

Table 4.1.b on page 13 presents the forecast capacity participating in LFC for the next several years. Also shown is the percentage of the capacity participating in LFC with respect to the expected annual system peak load.

The annual system peak load in Table 4.1.b is consistent with the recent decreases in annual system peak load, and the expected increase in the next few years. The 1993 Peak was taken from the 1994 edition of "Power Industry of Ukraine."[1]. Indexing of the 1993 figure to estimate future annual peak demands was done using Figure 8, Median Scenario, Page 15, World Bank Report Number 11561-UA.[2]

Table 4.1.b shows that in the next few years the percentage of capacity participating in LFC is going to increase because of decreasing demand, and increase because of benefits of the hydro and thermal rehabilitation projects. In the later years, 1999, 2000 and 2001, the sharp increase in regulating capacity results from the Dnestrovskaya Hydro Pumped Storage Facility coming on line.

The table does not need to take into account generating units that may be retired or out of service for maintenance because the table only deals with capacity planned to available for participating in LFC and On-Line Economic Dispatch, and with the forecast annual system peak.

The target percentage for the ratio of frequency regulating capacity (MW) to the annual system peak (MW) is 10 percent for the isolated Ukraine power system.

By contrast, UCPTE (a large interconnected power system) recommends 6.5 percent reserve (2.5 percent capacity for the primary control loop, and 4.0 percent capacity for the secondary control loop).

Table 4.1.b shows how and when these UCPTE percentages will be reached. The bottom portion of the Table shows how the planned primary and secondary capacity compares to the 2.5% and 4%

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1 "Power Industry of Ukraine," by The Ministry of Power and Electrification of Ukraine, published in Kiev in 1994.

2 "Ukraine, Power Demand and Supply Options," World Bank Report No. 11561-UA, Prepared with the International Energy Agency for the G-7; May 6, 1993; Country Department IV, Europe and Central Asia Region.

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UCPTE guidelines. Under the above assumptions and analysis not until the year 2000 will Ukraine have enough capacity in the secondary control loop to consider interconnection with the UCPTE power system.

It is assumed that hydro capacity will not be used to make up for the shortage of thermal capacity in the secondary control loop. To so use the hydro capacity in the secondary control loop would deplete the reservoirs. The water reservoirs in the Dnieper and Dniester Rivers needs to be managed and conserved. Water use planning on these two rivers involves years of expected usage, not days or weeks.

If Ukraine wishes to sell electric energy to other countries before interconnection operation in 2000, there are two alternatives.

1. Connect the generating unit directly to the other countries power system, as is already done in western Ukraine; and,
2. Use a back to back DC-DC inverter at the point of interconnection between the Ukraine power system and the neighboring countries power system.

The recommendations of this report are relatively insensitive to changes in the above tables. The tables are intended to only show that the Ukraine power system is deficient in the amount of capacity participating in LFC and On-Line Economic Dispatch for the next several years, and that work should begin as soon as possible on all projects that contribute to improving frequency regulation.

Furthermore, the tables indicate that the restoration of governors at hydro and thermal plants, and the rehabilitation of hydro plants, will make a significant contribution to improving frequency regulation. The completion of the Dnestrovskaya Hydro Pumped Storage Facility will contribute to the percentage of capacity participating in LFC in the future, when the facility is completed, and when the load has risen.

Conservation measures would also help these problems by reducing the system load. Time of Use (TOU) tariffs for large industrial energy users would significantly reduce the peak demand on the system, without having to involve retail customers in such programs.

The Ukrainian power system can probably continue to operate as it is operated now for a long time to come. The only significant wear is on the compressors and switch gear involved in the excessive starting and stopping of hydro generating units. Swings in frequency occur slowly and appear not to be damaging the equipment. Generators are not swinging widely to drive frequency back toward 50 Hertz. Accumulated time error is not a factor in Ukraine. Nuclear plants have in place procedures to reduce generation and to disconnect from the system when frequency is too high or low for too long a time. Reduced frequency does not save fuel or reduce electric consumption by the load; automatic control systems, such as thermostats, transcend frequency variations in the long term.

4.1 Regulation of Frequency (Continued).

Source of Capacity		Amount of Capacity Participating in LFC. (MW)		Status		Estimate of When Available
Dneprovskaya Hydro No. 1, and Kremenchug Hydro		1,100.		Existing		Now.
Future contribution from existing hydro plants (Projects 1 and A).		900.		Planned		1/4 in 1996; rest in 1997-1998.
Future contribution from existing thermal plants (Project 2).		1,500.		Planned		1/4 in 1996, rest in 1997 - 1999.
Dnestrovskaya Hydro Pumped Storage Facility (Project B).		2,900.		Planned		1/3 in 1999, rest in 2000 - 2001.
Total		6,400.				

Table 4.1.a Expected sources of increased capacity to participate in Load - Frequency Control. The projects that are to create the increased LFC capacity are shown in parentheses.

4.1 Regulation of Frequency (Continued).

Control Loop	Description	1993	1994	1995	1996	1997	1998	1999	2000	2001
Primary										
	Existing Hydro (MW).	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100
	Future Hydro Rehab. (MW).				90	270	450	630	810	900
	Dnestrovskaya HPS (MW).							900	1,900	2,900
	Total Primary Control (MW).	1,100.0	1,100.0	1,100.0	1,190.0	1,370.0	1,550.0	2,630.0	3,810.0	4,900.0
Second.										
	Future Thermal Rehab. (MW).				150	450	750	1,050	1,350	1,500
	Total Secondary Control (MW).	0.0	0.0	0.0	150.0	450.0	750.0	1,050.0	1,350.0	1,500.0
	Total Prim. + Secondary (MW).	1,100.0	1,100.0	1,100.0	1,340.0	1,820.0	2,300.0	3,680.0	5,160.0	6,400.0
	Annual Peak Load (GW).	31.5	31.1	30.8	30.4	30.8	31.1	31.5	31.9	32.6
	Percent Primary Control (%).	3.5	3.5	3.6	3.9	4.4	5.0	8.3	11.9	15.0
	Percent Secondary Control (%).	0.0	0.0	0.0	0.5	1.5	2.4	3.3	4.2	4.6
	Percent Primary Plus Secondary Control (%).	3.5	3.5	3.6	4.4	5.9	7.4	11.7	16.2	19.6

Table 4.1.b. The forecast capacity (GW) expected to be participating in Load - Frequency Control (LFC) over the next several years. Also show is the percentage of the primary, secondary, and combined primary plus secondary capacity as a percentage of the estimated annual system peak. Gigawatt (GW) = 1,000 MW.

UCPTE guidelines call for 2.5 % capacity for primary control and 4 % capacity for secondary control. Not until the year 2000 does the percent secondary control exceed the 4 % UCPTE guideline.

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4.2 Regulation of Time.

Accumulated time error is the integral of the frequency deviation over a time period. The time error is expressed in units of seconds. The time error is the difference between 50 Hertz system time and astronomical time.

This one number for time error is an excellent measure of the health of an alternative current (AC) power system. It is one number that reflects the total health (installed capacity, maintenance programs, transmission system, fuel supply, relations with neighboring power systems, tuning of governors and LFC equipment, etc.) of the power system.

Ukraine does not have a standard or a practice of regulating time by the 50 Hertz power system. They do, though, try to keep the time error near zero by keeping the long term frequency deviation near zero.

Neither measurements nor statistics on time error are kept.

Not tracking and minimizing time error is a major cultural difference in the design and operation of Ukraine power system as compared to some other utilities. The use of time error as a measure of the health of the Ukraine power system is not possible.

In Ukraine, astronomical time is distributed to the public by radio. In buildings and factories wall mounted clocks are synchronized by a local controller. Television also distributes astronomical time to the public. By contrast, in Europe, North America and other countries, the 50 (or 60) Hertz power system frequency is regulated so that the difference between power system time and astronomical time is within acceptable limits (usually 12 to 30 seconds).

The performance of the Ukraine power system with respect to UCPTE standards for maximum frequency deviation and for accumulated time error should be regularly monitored by the National Dispatch Center to track the improvement in frequency regulation as the various projects described elsewhere in this report are completed. See Recommendation 6.5.1, page 28 below.

4.3 Hydro Plants.

At many hydro plants, the governor control systems are over 30 years old. The mechanical parts are serviced, but they are worn. Larger than normal dead band of frequency regulation is the result. For example, a motor driven wire wound potentiometer serves as set point; such systems, though used 30 years ago when the power plants on the Volga River controlled frequency, are unacceptable now. Also, parts of the governor systems use vacuum tubes which are less reliable than solid state electronics, and replacement parts are hard to obtain.

Generation commands are conveyed to the plants by raise pulses and lower pulses. This method, while simple and used in the early years of power system control, is not reliable and secure. Raise and lower pulses are often corrupted by noise in the communications path, and so the generator does not receive the correct command. The effect on the system is frequency and time deviations.

4.4 Thermal Plants.

Thermal plants are involved in primary, secondary, and tertiary control.

To have good primary control, the governors of the thermal plants need to be in good working order. In Ukraine, this may require the restoration or replacement of some governors and associated equipment. In this control loop the governors are expected to hold the operating point that they are given.

To have good secondary control, the governor and the thermal plant needs to move the output of the generating unit up or down within a relatively narrow band, say, 10 percent. For an 800 MW unit, the regulating band is around + / - 40 MW. The dead band of a governor in need of adjustment could be + / - 40 MW. And so this generating unit cannot effectively participate in LFC.

In fact, the operation of this unit may hinder LFC. The dead band of + / - 40 MW is a regulating range of 80 MW. Two hydro generating units at Kremenchug would have to travel through 100 percent of their regulating range (about 40 MW each) to compensate for the dead band of the one 800 MW plant. Hydro capacity for regulating frequency is a very precious resource (just like load capacity is a precious resource for the thermal plant), and so the hydro capacity needs to be protected.

To have good tertiary control in the power system, the thermal units have to move up and down to follow the load. This load following is already done in Ukraine, and is accomplished by telephone conversations between the plant operators, and the National Dispatch Center. A typical movement for an 800 MW units is to go from 450 to 750 MW in 6 hours. The actual rate of change is 0.8 MW per minute. Each unit has a maximum rate of change it can accommodate, and the number is around 6 MW per minute. The maximum rate of change protects the critical mechanical elements (boiler, pipes, turbine) from thermal shock (sudden temperature changes). The rate of change limit also recognizes the changes in coal feed, boiler firing, and ash handling that must occur at the same time that the power output change is requested.

The staffs of the thermal generating units do cooperate with the National Dispatch Center to adjust the operating points of the units to support system load and system frequency requirements. At this time the new requirements are phoned to the plants.

In the future the request from the National Dispatch Center to the units should be automatic, by way of electronics and communications channels. At the generating unit, the upper and lower limits of regulation that are set by the plant, and the maximum rate of change for the unit, would be recognized and adhered to in such an automatic system. The plant operator always has ultimate control of the plant even in automatic LFC and On-Line Economic Dispatch mode.

4.5 National Dispatch Center.

At the National Dispatch Center the following much needed new features cannot be added to the existing computer. These features will contribute to restoring frequency control, controlling power flows on interconnections, and the minimizing the cost of fuel burned.

Load Frequency Control;
On-Line Economic Dispatch;
Generation Bidding and Scheduling among the power system members; and,
Inter - Enterprise Energy (Megawatthour, MWH) Collection and Reporting.

The Videoton computers are 10 years old, and are at the end of their useful life. They come from Hungary, and are no longer made. Main memory is only 1 Megabyte. The computers run 75 - 80 percent loaded most of the time. Maintenance is not a significant problem now, but as years go on, service and spare parts will be harder to get.

The high utilization of the main processing unit does not permit adding new features without removing existing features.

4.6 Communication Channels.

Communication channels are either power line carrier, bundled cables, or leased lines from the telephone company. The channels are heavily utilized with data and voice frequency-multiplexed on the same analog channels. Microwave channels are not used.

The terminal equipment at both ends of the communications channels is old. Being electronic the terminal equipment is at the end of its useful life of 10 years.

Faster data rates are needed to move more data faster. Modern electronic communication technology can be used to improve the situation. For example, modern modems operate at 14.4 kilobits per second over traditional, standard 3,000 Hertz wide telephone channels whereas previously the highest data rate on such channels was 300 bits per second.

At Dneproznergo Regional Dispatch Center they recently enhanced a voice grade data channel to operate at 9,600 bits per second by the use of modern modems and by the addition of a telephone line amplifier in the circuit. This demonstrates that such upgrades are possible.

Though the communications equipment at each end of a circuit needs to be upgraded, the channel itself is adequate. Additional channels in telephone cables will be needed in the future as new equipment for control of the generating plants and for collecting the hourly megawatthour readings is installed.

4.7 Inter - Enterprise Energy (Megawatthour, MWH) Collection and Reporting System.

There is no automatic hourly megawatthour reporting system, with communication channels to the National Dispatch Center. There are energy (MWH) meters on all plants and at key stations, but the readings are collected manually.

The new structure of the electric power sector needs an hourly automatic collection of these readings from all of the following locations:

a. Generating plants (thermal, hydro and nuclear);
b. Points of delivery to customers (LECs, cogenerators, large customers, etc.); and,
c. Interconnections to neighboring power systems.

Modern energy management systems for control centers include such hourly automatic data collection from the plant and station meters. Any new control and communication system for the Ukraine should include this feature as standard at the time of delivery.

The projects proposed here satisfy the needs expressed in a recent Draft Terms of Reference from the World Bank, "Scoping Study: Metering and Communications Requirements for the Ukrainian Power Pool.[3]"

4.8 Performance Of Generating Units Operating Outside Their Design Limits.

Hydro and thermal generating units are being asked to respond quickly to changes in load in ways that they were not originally designed to handle.

The hydro units at Dneprovskaya are consuming their useful life faster than planned because each day they are cycling on and off line three times faster than planned. Disconnect switches and compressors are wearing out. Bringing units on and off line is difficult because of the bus switching arrangement of 3 or 4 generators on one bus connected to one step-up transformer.

At coal fired plants, the quality (heat content and ash content) of coal has fallen significantly, and consistency (the statistical distributions of heat content and ash content within a given shipment of coal) has spread out drastically. The plants were not designed to burn such coal. In some cases enough of the low heat content coal cannot be fed to be boiler fast enough to sustain the desired output of the generator. The ash handling equipment is over whelmed by the amount of ash coming out of the plant. Slagging inside the boiler occurs at locations other than where the slagging was designed to occur.

All of these factors cause the plants to wear out faster, and to be less able to participate in primary, secondary, and tertiary control of the power system.

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[3] "Scoping Study: Metering and Communications Requirements for the Ukrainian Power Pool," Draft Terms of Reference, The World Bank, June 1994.

5 OPERATIONAL AND PROCEDURAL FINDINGS

The Ukrainian engineers and managers know the deficiencies of their control, dispatch, and communication system. The do a very admirable job of keeping the system running every day. They also know what needs to be done to improve the system, while maintaining least cost operation.

5.1 Financial.

Financial resources are needed to enable the Ukrainian engineers to implement their solutions to the problems. Funding of the foreign exchange part of the projects described in the report is a step in that direction.

5.2 Monitoring of Accumulated Time Error.

Ukraine desires to be connected to the UCPTE power system. UCPTE guidelines require participation in time corrections. The National Dispatch Center should begin measuring and recording accumulated time error so that the performance of the Ukrainian power system with regard to this performance parameter can be reviewed and improved.

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6 RECOMMENDATIONS (TECHNICAL, OPERATIONAL AND PROCEDURAL)

The following measures are recommended to upgrade the system control equipment and procedures in order to facilitate the cost - effective operation of the Ukraine power system, and to enable Ukraine to re-integrate with its neighboring countries.

1. Minimize the dead band of governors at hydro and thermal plants. In some cases it may be necessary to restore or replace just the governor system at the generating unit. In other cases, more extensive work at the unit may be necessary.

   This measure addresses problems in the primary control loop of the power system.

2. Place as many hydro and thermal units on LFC as possible. In addition to the governor upgrades mentioned above, this measure requires upgrading the computer system at the National Dispatch Center, and installing electronic data acquisition, control, and communications equipment between the National Dispatch Center, the eight Regional Dispatch Centers, generating units (hydro, thermal and nuclear), and key sub-stations.

   This measure addresses problems in the secondary and tertiary control loops of the power system.

3. Implement On-Line Economic Dispatch function at the National Control Center, with on-line automatic control of as many hydro and thermal generating units as possible.

   This measure addresses problems in the tertiary control loop of the power system.

4. Implement on-line real-time data collection of inter - enterprise energy (MWH) readings so that member companies and neighboring utilities can be billed on an hourly basis.

   This measure is required for the operation of the Ukraine power system after the planned restructuring of the electric power sector.

5. Complete the Coal Sourcing Study, which hopefully will contain an action plan to get better quality, and better consistency in coal quality, for the coal fired generating units.

   This measure enables improvement in the performance of coal fired power plants in the secondary and tertiary control loops of the power system.

6. Complete the planned hydro rehabilitation program. This project provides the new governors mentioned in Item 1, above. This project also provides additional benefits for the Ukraine power system: increased capacity, increased availability, reduced maintenance costs, and reduced leakage of oil into rivers.

   This project contributes to the primary, secondary, and tertiary control loops of the power system.

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7. Complete the Dnestrovskaya Hydro Pumped Storage Facility. This additional hydro capability will (a) add more regulating capacity to the system, and (2) enable the thermal units to run more at base load by pumping at off peak times.

   This project contributes to the primary, secondary, and tertiary control loops of the power system.

Six projects have been identified to address the measures listed above. In the next few Sections the projects will be defined, and the priorities, schedules and scheduling discussed.

The details (assumptions, costs, material and labor, extent of implementation, alternatives for future enhancements, etc.) of the Projects are presented in Annex 1, beginning on page 49.

Variations of these Projects are possible. The Ukraine power system engineers, in conjunction with The World Bank, will develop the technical and commercial specifications used in International Competitive Bidding (ICB). It is those specifications, and not this report, that will define what modern control, communications and dispatch systems Ukraine ultimately purchases.

6.1. Project Descriptions.

So as to provide The World Bank with confident project cost estimates, the following projects were defined.

Additional technical details and estimated costs for the projects are contained in Annex 1.

6.1.1. Restoration Of LFC and Associated Equipment At Hydro Plants.

This project improves the primary control loop of the power system.

Restore or replace the load - frequency control equipment at all hydro generating plants. This work includes the reconstruction or replacement of governors (specialty hydraulic and electronic parts) for both plants and units, and such new equipment as instrumentation, power transducers, energy meters, telemechanical (telemeasure, telesignal and telecontrol) equipment, and communications equipment.

Oil and gas fired thermal generating plants should also be controlled so that the on-line economic dispatch function in the computer at the National Dispatch Center can change the generation on these plants automatically and as often and as required. This directly contributes to the national goal of reducing the use of imported oil and gas and off - load the hydro plants.

This work has already been incorporated in to the specification for the hydro rehabilitation project. An estimated cost is developed in Annex 1 for the LFC portion of the project so that the cost and benefits of LFC improvements can be evaluated.

6.1.2. Restoration Of LFC and Associated Equipment At Thermal Plants.

This project improves the performance of the primary, secondary and tertiary control loops of the power system.

In this project the governors and associated equipment at key thermal power plants will be restored or replaced. A technical specification of how good the restored or replaced governors have to be (in terms of dead band, response time, etc.) needs to be developed by the Ukraine engineers.

Appropriate interfaces to other power plant systems, such as coal and ash handling, boiler firing, etc., needs to be worked out. An integrated design that enables the generating units to respond within it's limits needs to be developed. It may not be appropriate to just replace the governors; work on associated power plant systems may be needed.

Ownership and responsibility for the maintenance of the governors and associated equipment at the thermal generating units needs to be addressed. Since at this time The World Bank is not financing loans to the thermal plants, an accounting method (such as leasing) needs to be developed that allows the restoration work to be done at the thermal plants in support of the goal to finance the improvements and benefits at the National Dispatch Center.

6.1.3. Data Acquisition and Control Equipment Between Plants and National Dispatch Center.

This project improves the secondary and tertiary control loops.

It is necessary to improve the telemeasure, telesignal and telecontrol information to and from all generating plants (hydro, thermal and nuclear).

The new system should include the following quantities from all generating units, whether or not the generating units participates in LFC and On-Line Economic Dispatch on any given day.

raise / lower commands;
unit power (MW and MVAR);
unit status (off line, on-line-manual, on-line-automatic, tripped);
type of fuel (oil or gas) burned at combination plants;
upper and lower regulating limits as set by the plant operator;
energy (MWH) meters;
collection of hourly MWH readings;
remote terminal unit; and,
associated communications equipment and channels.

Though the present telemechanical system may handle most of this additional information, the new computers for the National Dispatch Center (Project 6) makes the handling of all of this data in the new control center possible.

Ownership and responsibility for maintenance of the electronics and associated equipment at the thermal and nuclear generating units needs to be addressed. Since at this time The World Bank is not financing loans to the thermal and nuclear plants, an accounting method (such as leasing) needs to be developed that allows the restoration work to be done at the thermal and nuclear plants in support of the goal to finance the improvements and benefits at the National Dispatch Center.

6.1.4. Data Presentation and Routing Computers For Eight (8) Regional Dispatch Centers.

This project enables the eight (8) Regional Dispatch Centers to monitor the information exchanged between the National Dispatch Center and the plants and substations. Enough computer work stations and communications equipment will be installed to enable the monitoring and reporting of the data exchanges.

The system should be modular, and should be able to be developed into a supervisory control and data acquisition system when the need and justification exists.

6.1.5. Inter - Enterprise Energy (MWH) Collection (From Key Sub-stations) and Reporting.

This project enables the intercompany and interconnection billing that will be needed for the newly structured power sector in Ukraine.

Meters, remote terminal units (telemechanical), and communications equipment and channels will be installed in the field for this project.

The equipment at the National Dispatch Center for this project is contained in Project 6, below.

Readings from the generating plants is collected by the equipment in Project 3, Data Acquisition and Control Between Plants and National Dispatch Center.

Annex 3 provides background information on how generating plants, neighboring utilities, local utilities, and large customers are billed in interconnected power system operation. Metering and billing in interconnected power system operation is commented on in Annex 3, since the method is different than the method used for retail and commercial billing systems.

6.1.6. Implement LFC and On-Line Economic Dispatch By Upgrading the Computer System At the National Dispatch Center.

This project improves the secondary and tertiary control loops of the power system.

This project also enables the inter - enterprise and interconnection billing of the newly re-structured electric power sector of Ukraine. All of the billing information collected from the equipment installed in the field in Projects 3 and 5 is processed at the National Dispatch Center.

This project calls for the upgrade the dispatch computer system at the National Dispatch Center. The following features are to be included in the new system:

- Load - Frequency Control (LFC);
- On-Line Economic Dispatch;
- Supervisory Control and Data Acquisition to support LFC and On-Line Economic Dispatch;
- Interchange Scheduling and Billing;
- Inter - Enterprise Energy (MWH) Collection and Reporting;
- Generation Bidding and Forecasting Function (special, see note below);

This work will involve new computer hardware and software, CRTs, displays, communications equipment, and training.

As described in more detail in Annex 1, this system will contain just enough work stations, software and similar equipment to support the functions listed above. It is envisioned that the system will be composed of work stations connected to a local area network.

At a later date, when justified, many other functions can be added, such as

State Estimation,
Transmission Operating Logging and Reporting,
Contingency Analysis,
On-Line Load Flow,
On-Line Short-Circuit Calculations,
Load Management and Control,
Automatic Mapping and Facilities Management (AM/FM),
etc.

The Generation Bidding and Forecasting Function will be a special function developed for the Ukraine power system. It should fit in well with the standard energy management system (EMS) that will be obtained. By being part of the EMS, the new bidding and forecasting function will be smoothly integrated into the dispatch operation.

6.1.7 Related Projects.

The following three projects can significantly contribute to better frequency regulation. The projects should be approved and implemented.

6.1.7.1 Rehabilitate Hydro Plants.

Rehabilitate the following hydro plants (per an SGI list). This project is being proposed and managed by the Hydro Engineering and Operations Department of Minenergo.

Dneprodzerhinsk Hydro
Dneprovskaya Hydro No. 1
Kakhovka Hydro
Kanev Hydro
Kiev Hydro
Kremenchug Hydro

6.1.7.2 Complete Dnestrovskaya Hydro Pumped Storage Facility.

Complete the construction of the Dnestrovskaya Hydro Pumped - Storage (HPS) Facility. This facility provides much needed frequency regulating capacity (2,900 MW planned). If this project is completed, its completion will be so far in the future that it will have little effect on the present near term ability to regulate frequency. In the distant future it will relieve the burden of frequency regulation on the existing aging hydro plants.

In this project particular attention and help needs to be placed on the relay protection and emergency condition handling of the Dnestrovskaya motor - generators. Also, both the static (load flow) and the dynamic (transient stability) of the transmission network associated with this pumped - storage facility should be reviewed by the Regime Department of the National Dispatch Center, and Energosietproekt.

6.1.7.3 Coal Sourcing Study Of Ukraine.

The quality and the consistency of the coal received by the thermal power plants is poor, and is a significant contributor of the thermal plant's inability to contribute to On-Line Economic Dispatch, LFC, and load following.

For example, a plant that was designed to get 5,000 kilo calorie per kilogram of heat content and 22 per cent ash content is now getting coal with 3,200 kilo calorie per kilogram heat content and 48 per cent ash. This causes sever problems at the plant (coal and ash handling, slagging, derated output, etc.), and makes it harder for the plant to contribute to the requests of the National Dispatch Center. Under these conditions the regulating range of the plant is + / - 50 MW; the plant engineer reports that with better coal the regulating range would be twice that, or + / - 100 MW. For the National Dispatch Center this is a significant increase in the contribution to frequency regulation.

Therefore, the Ministry of Energy and Electrification of Ukraine and The World Bank should proceed with the study of coal sourcing, with an emphasis on getting coal of a high and consistent quality to the thermal plants.

6.2 Project Priorities.

6.2.1 Most Important.

The most important priority is to get the hydro and thermal LFC and associated equipment rehabilitated. The "objects of control" need to be in good working order.

Similarly, work should proceed on the Dnestrovskaya Hydro Pumped Storage Project, and the Coal Sourcing Study.

6.2.2 Second.

At a lower priority, but in parallel with the above projects as described in Section 6.3, below, LFC and On-Line Economic Dispatch needs to be implemented at the National Dispatch Center. Corresponding work on the Data Acquisition and Control System for the Plants (Project 3), and the Inter - Enterprise Energy (MWH) Collection and Reporting System (Project 5) can proceed.

6.2.3 Third.

The Data Presentation and Routing System (Project 4) for the eight Regional Dispatch Centers (RDCs) can proceed after the work on the National Dispatch Center (RDC) is well underway.

The signals between the National Dispatch Center and the generating units and sub-stations do not have to pass through the RDCs, but administratively it would be wise if they did pass through the RDCs.

6.3 Project Scheduling.

It is recommended that all six projects be worked on at the same time. The projects should <u>not</u> be worked one after the other. Ukraine needs the performance improvements now in all three (primary,

secondary, and tertiary) control loops. The benefits need to be obtained from where ever they can be obtained, and as fast as possible.

Project 5, Inter - Enterprise Energy (MWH) Collecting and Reporting, can be deferred if the reorganization of the electric power sector is deferred.

The installation of the new equipment at the National Dispatch Center (Project 6) should proceed with all deliberate speed. This computer system is at the heart of the operation of the Ukraine electric power sector.

1. Frequency regulation and time error is handled by the LFC Function (Projects 6, 1 and 2).

2. Reduction in cost of fuel used is handled by the On-Line Economic Dispatch Function (Projects 6 and 3). The On-Line Economic Dispatch function creates all of the cost savings that are used to fund the other five projects. The fuel savings are significant, and carry the costs of all of the other components of the project.

3. Inter - company and interconnection billing is handled by the Inter - Enterprise Energy (MWH) Collection and Reporting Project, the Data Acquisition With the Plants projects, and the Generation Bidding and Forecasting Function (Projects 6, 3 and 5).

Many functions, such as On-Line Economic Dispatch, and Data Acquisition, can be operational and useful before LFC and control equipment is fully operational in the field. Even in a monitoring and advising mode the new equipment at the National Dispatch Center is valuable. Raise and lower commands can be phoned to the power plants, as is done now.

The implementation of the projects of this report has been spread across 3 to 5 years. Considering the quick payback (about 6 months for all 6 projects), the work should be accelerated so that the projects are completed in 2 to 3 years.

6.4 Project Schedules.

This Section contains Gantt charts which present in general form the planned stages and durations of the projects.

Chart 6.4.a, page 29, shows the general schedules for restoration of the governors at plants, and associated load - frequency control equipment.

Chart 6.4.b, Page 31 shows the general schedules for the Regional and N onal Control Centers, Data Acquisition and Control With Plants, and Inter - Enterprise Energy (MWH) Collection and Reporting Projects.

The key difference between Charts 6.4.a and 6.4.b is the additional activity titled "Hold For Unit Outage" in Chart 6.4.a. This additional activity permits the schedule to slide forward in time until a convenient outage of the generating unit occurs.

6.5 Activities.

6.5.1 Monitoring and Reporting Time Error.

The performance of the Ukraine power system with respect to UCPTE standards for maximum frequency deviation and for accumulated time error should be regularly monitored by the National Dispatch Center to track the improvement in frequency regulation as the various projects described elsewhere in this report are completed.

A frequency and time deviation meter (instrument) costs about $10,000. Such a unit should be provided at no cost to the National Dispatch Center on a technical grant from a donor agency. The output of the meter should be connected to the existing data collection system of the National Dispatch Center and the data archived regularly (say, hourly) along with other key system measurements that are already being archived.

6.5.2 Agreements Between the National Dispatch Center and Generating Plants.

It is necessary that the National Dispatch Center always have the authority, responsibility and method to regulate watt and var flow. How well they perform these regulation functions is measured by frequency deviation and time error (for watts) and system voltage profile (for vars).

In the new structure of the Ukrainian electric power sector there should be provisions in the contracts between the National Dispatch Center and the generating plants (including co-generators, independent power producers, large customers, and local electric companies) for the following.

- participation in frequency control;
- participation in correction of time error;
- participation in voltage control (supply or absorb vars);
- availability (up time) of generating units;
- adherence to agreed upon schedules;
- maintaining an agreed upon LFC regulation band (for example, 100 MW);
- National Dispatch Center providing the governor settings, even though the plants may own or [illegible] the governor mechanism itself;
- periodic testing and calibration of the governors; and,
- response time to fix problems with a governor and related LFC equipment.

The agreements should contain both bonuses for those who exceed the requirements, and penalties and sanctions against those who fail to meet the requirements.

6.5.3 On-Line Dispatching Of Thermal Generating Units.

It may be valuable for a representative from the National Dispatch Center to visit the control center of an electric utility that uses thermal power plants to contribute to secondary and tertiary control loops. The visitor could see how other utilities in such situations deal with the day to day problems of, particularly, coal fired plants. These utilities deal daily with the usual problems of coal quality and consistency, slagging, coal mill (pulverizer) problems, frozen coal piles, boiler leaks, etc. yet still participate in second and tertiary control of the power system.

Activity.	Milestone.	D	u	a	t	i	o	n	,	m	o	n	t	h	s
	Start Project.	M													
Identify Needs.			6												
Write Technical Specifications.				3											
Prepare Bid Specifications (Technical and Commercial).				4											
Distribute Request For Bids (RFBs).					1										
Prepare Bids (by vendors).						2									
	Receive and Open Bids.						M								
Evaluate Bids.								4							
	Award Contracts.								M						
Build equipment and systems.										9					
Ship equipment and systems to site.											1				
Hold For Unit Outage.											6?				
Remove Old; Install New.												1			
Start up and Test.													1		
	Acceptance of System.													M	
System Is Operational (In Service).															X
Training.										X	X	X	X	X	X
Documentation.										X	X	X	X	X	X

Chart 6.4.a Gantt Charts For Load - Frequency Control Projects (Hydro and Thermal). The above chart shows a typical development schedule for the work on the load - frequency control equipment at hydro and thermal generating units (Projects 1 and 2). Numbers are the durations (in months); M are milestones (which have no duration); and "X" are activities extending over several months.

Activity.	Milestone.	D	u	a	t	i	o	n	,	m	o	n	t	h	s
	Start Project.	M													
Identify Needs.			6												
Write Technical Specifications.				3											
Prepare Bid Specifications (Technical and Commercial).				4											
Distribute Request For Bids (RFBs).					1										
Prepare Bids (by vendors).						3									
	Receive and Open Bids.						M								
Evaluate Bids.								4							
	Award Contracts.								M						
Build equipment and systems.										18					
Ship equipment and systems to site.											1				
Remove Old; Install New.												6			
Start up and Test.													6		
	Acceptance of System.													M	
System Is Operational (In Service).															X
Training.										X	X	X	X	X	X
Documentation.										X	X	X	X	X	X

Chart 6.4.b Gantt Chart For Control Centers and Data Systems Projects. The above chart shows a typical development schedule for a control centers, inter-enterprise energy collection, and data acquisition and control (Projects 3, 4, 5 and 6). Numbers are the durations (in months); M are milestones (which have no duration); and "X" are activities extending over several months.

7 BENEFITS

7.1 Quantitative Benefits.

The annual fuel cost of the electric power sector in Ukraine is $ 2,045 million.[4] An estimated 2.5 percent of this cost can be saved by On-Line Economic Dispatch (OLED) of all generating units. Thus, $ 51.1 million can be saved annually.

If less than all of the units participate in On-Line Economic Dispatch, then the benefits should be appropriately reduced. For example:

Per Cent of Thermal Plants Participating In Governor Work and OLED.	Estimated Reduction In Savings	Estimated Annual Fuel Cost Savings
100 %	0.	$ 51.1 million
75 %	12.5 %	$ 44.7 million
54 %	23. %	$ 39.3 million
50 %	25. %	$ 38.3 million
below 50%	See next paragraph.	See next paragraph.

Even with out automatic control of a generating unit by the On-Line Economic Dispatch function, the economic benefits of a new energy management system will still occur because the economic operating point can be phoned to the plant on an appropriate period, say 4 times daily. Even reducing the benefits in the range 100 % to 50 %, as was done above, is conservative and the reduction in estimated savings may be too much.

The above estimate is consistent with the 2.5 percent reduction in cost of fuel burned used in the recently proposed upgrades to the Lithuanian Power System (also a former Soviet power system). The two and one-half percent savings was used by the World Bank mission[5]. Similar savings are reported in the March, 1998 issue of Transmission and Distribution Magazine[6].

Power system engineering studies can provide a more accurate estimate for the Ukraine system if a more accurate estimate is needed (see recommendation 11.4, page 45, below).

To realize these financial benefits,

1. The load frequency control equipment at the key hydro and thermal generating plant must be restored to their original or better condition;

2. The LFC, On-Line Economic Dispatch, Inter - Enterprise Energy (MWH) Collection and Reporting, Interchange Scheduling and Billing Function, and Generation Bidding and

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[4] The $ 2,045 million fuel cost figure was provided by The World Bank, which originally got the figure from the Ministry of Environmental Protection of Ukraine.

[5] "Lithuania: Power Rehabilitation Project," Project Economic Analysis, Annex 5.2, Page 3 of 3.; World Bank document.

[6] "Technical and Cost Benefits Justify SCADA / EMS," by Thomas A. Kutscher, P.E., Project Engineer, Black & Veatch, Engineers and Architects, Transmission & Distribution Magazine, March, 1988.

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Forecasting Functions need to be operational in a new computer system at the National Dispatch Center. The computer will track generation cost (in either the new or the existing power sector structure), and assign generation to the most economic units. The load frequency control equipment at the plants executes the directives from the central computer;

3. The data acquisition and control system between the National Dispatch Center and the generating units has to be operational; and,

4. The Inter - Enterprise Energy (MWH) Collection and Reporting System equipment needs to be operational at the key sub-stations.

7.2 Un - quantified Benefits.

In addition to the hard savings presented in Section 7.1, there are other benefits. Some of the benefits could be quantified (but are not in this report), and other benefits are difficult (or debatable) to quantify. Regardless, they are benefits to the Ukrainian power system.

a. Lower maintenance costs because of less maintenance on old governor control equipment, computers, and communication equipment and lines.

b. Export sales permitted by closing ties and synchronizing to other power systems. Capacity that was previously used for LFC participation can then be re-allocated for generating export sales. The new computer system at the National Dispatch Center will automatically take care of this re-allocation and optimization (minimization) based upon fuel cost.

c. Reduction in spinning reserve because of ties to other power systems. For each 1,000 MW of spinning reserve that is not needed, $ 1.5 billion is power plant capital is avoided (at $ 1,500 per kW plant cost).

   To reduce the 10% percentage (MW participating in LFC to MW annual system peak) to 6.5% is a 3.5% reduction. With a annual peak load of about 30 GW, the 3.5% reduction is 1,050 MW reduction in capacity. The savings is $1.575 billion.

d. Less revenue lost during outages because of quicker restoration of service to customers. A new SCADA system for the transmission system and part of the distribution system would enable the control centers to learn quicker and with more detail what equipment or lines have tripped out, and enable quicker restoration of customers.

e. Inter - enterprise metering and communications for the newly restructured electric power sector is implemented along with, and as an integral part of, the above LFC and On-Line Economic Dispatch Projects. No new, separate projects and systems are needed.

f. An estimated additional 1 percent reduction in fuel cost is possible when the optimal power flow calculation is performed in the dispatch computer, <u>and</u> the corresponding changes in Var flow on the transmission system is executed in the power system. This reduction is a savings of $ 20.5 million annually.

This opportunity for savings, though, needs to have the means to adjust Vars in the field. This needs to be investigated before this option is exercised. Any additional equipment costs at the start of the project will lengthen the pay back period.

g. With more units participating in frequency regulation, each generating unit participating in LFC will see less movement of their operating point, and thus less wear and tear, and maintenance on their mechanical systems (turbine, generator, bearings, pumps, boiler, etc.).

h. With the computer developing on-line the economic operating points, adhering to contracted interconnection energy sales, and dispatching the units, the personnel of the National Dispatch Center can direct more of their attention to the broader issues and concerns of day to day dispatch.

8 QUALITY IMPROVEMENTS

Actions to improve quality should occur everywhere in the organization at once. Every person in the organization should be working to eliminate waste -- wasted fuel, wasted time, wasted material.

Considering the present state of the Ukraine power system (frequency varying wider than standard, facilities in need of rehabilitation, opportunities for export of electric energy limited by being disconnected from neighboring utilities, coal to boilers below design specifications for boilers, etc.), work ought to be proceeding on all areas simultaneously. Now is not the time to work on the second project only after a first project is finished.

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9 INVESTMENT PLAN

Table 9 on page 41 shows the time sequenced investment plan. This table assumes a loan approval and start of projects by mid 1995. Hence, expenditures begin in the middle of 1995.

Annex 5 on page 81 contains the spread sheet and lists the assumptions that were used in developing this investment plan.

The implementation of the projects of this report has been spread across 3 to 5 years. Considering the quick payback (about 6 months for all 6 projects), the work should be accelerated so that the projects are completed in 2 to 3 years.

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Project Number	Title	1995 FE $Mil.	1995 Local $Mil.	1996 FE $Mil.	1996 Local $Mil.	1997 FE $Mil.	1997 Local $Mil.	1998 FE $Mil.	1998 Local $Mil.	1999 FE $Mil.	1999 Local $Mil.	2000 FE $Mil.	2000 Local $Mil
1	Restore Hydro Plant LFC Performance.	1.027	0.316	2.054	0.632	2.054	0.632	2.054	0.632	2.054	0.632	1.027	0.316
2	Restore Thermal Plant LFC Performance.	0.819	0.252	1.638	0.504	1.638	0.504	1.638	0.504	1.638	0.504	0.819	0.252
3	Data Acquisition & Control For Plants.	0.414	0.120	0.621	0.179	0.621	0.179	0.414	0.120				
4	Enhance Regional Dispatch Centers.	0.400	0.128	0.800	0.256	1.200	0.384	0.800	0.256	0.800	0.256		
5	Inter - Enterprise MWH Collection & Reporting.	0.280	0.044	0.420	0.066	0.420	0.066	0.280	0.044				
6	Enhance National Dispatch Center.	0.780	0.321	1.170	0.482	1.170	0.482	0.780	0.321				
	Total (Including Hydro).	3.720	1.181	6.703	2.119	7.103	2.247	5.966	1.877	4.492	1.392	1.846	0.568
	Total (Excluding Hydro).	2.693	0.865	4.649	1.487	5.049	1.615	3.912	1.245	2.438	0.760	0.819	0.252
A	Hydro Rehabilitation.	xx	xx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx
B	Dnestrovskaya Hydro Pumped Storage.					xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx
C	Coal Sourcing Study.	xxxx	xxxx	xxxx	xxxx								

Table 9. Time Sequenced Investment Plan. This table shows the expected investment plan. This table presents expected cash flow; actual activity on the projects may be otherwise. See Annex 5 for the supporting spread sheet. Foreign Exchange -- FE; 'x' indicates activities in each quarter of the associated year for the three supporting projects A, B and C.

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10 COORDINATION OF WORK BY OTHER COMPANIES

The mission understands that other companies, including equipment suppliers (Landis & Gyr, Switzerland) and foreign utilities (Electricite de France, France) are also involved in the work to modernize system control and dispatch in Ukraine. Minenergo has to ensure that the various activities are properly coordinated ensuring proper phasing, consistency and avoiding conflicts and overlap.

10.1 Electricite de France (EDF).

Electricite de France (EDF) and the National Dispatch Center have signed a protocol and have begun work on a redesign of the information system of the National Dispatch Center. EDF has visited the Center and begun work.

The work of the World Bank and EDF should be coordinated so that the best system and the best financing is obtained ultimately for Ukraine.

10.2 Landis and Gyr (L&G).

Landis & Gyr (L&G, Zug, Switzerland) is working with the National Dispatch Center to develop a metering system for the interconnections with other power systems.

The work of the World Bank and L&G should be coordinated so that the best system and the best financing is obtained ultimately for Ukraine.

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11 ADDITIONAL INVESTIGATIONS THAT ARE RECOMMENDED

In the course of preparing this report, the following concerns were recognized by the author, or were reported by others (and the author agrees). It is understood that work is planned in many of these areas. The items are mentioned here so that they are not inadvertently lost.

11.1 Static and Dynamic Stability Associated With Dnestrovskaya Hydro Pumped Storage Facility.

Static and dynamic stability in the transmission system and generating plants when the Dnestrovskaya Pumped Storage goes on line needs to be investigated.

11.2. Safety of Hydro Civil Works.

Hydro plant rehabilitation should include inspection and monitoring of the earth and concrete works, in addition to the rework of the building, mechanical, and electrical parts of the system.

11.3. Quality of River Water.

Rework of hydro plant turbines will help keep lubricating oil out of river water. In many places river water downstream of the hydro plants is used for drinking water.

11.4. Validation of Cost Savings Assumptions; a Technical Assistance Grant.

The estimated reduction in fuel cost (2.5 % for watts and 1 % for vars) used in Section 7, Benefits, can be validated by studies. If these assumptions need to be validated, it is suggested that a technical grant (estimated to be $ 50,000) be obtained from a donor agency and the money used to buy the a computer, a printer, the PSS/E analysis software package from Power Technologies, Inc., and a weeks training on the software.

This software package will enable the Economic Operations Department of the National Dispatch Center to conduct the studies that will develop a pair of percentages (one for watts, the other for vars) that are representative of the Ukraine power system.

11.5. Adequacy of Sub - Stations and Transmission System.

This project has focused on the control, communications and dispatch of Ukraine. We have identified the system protection (relaying), modes of operation (pump or generate), and additional static and dynamic stability concerns raised by Ukraine about the Dnestrovskaya Hydro Pumped Storage Facility.

A more extensive investigation of the sub-stations and transmission system may be appropriate.

11.6. Limits of Generating Unit Regulation.

It would be good to list for each generating unit (hydro and thermal) the present and planned regulating range (upper minus lower MW limits). This will help identify and track the gain in regulating capacity that the National Dispatch Center gets each year from the hydro and thermal rehabilitation projects. Annex 4, page 74 contains the format of such a Table.

11.7 Emergency Control System.

This report does not touch upon the design, operation, and maintenance of the old Russian Emergency Control System. Under the Russian operated power system the six echelons of the Emergency Control system were a very important part of system operation.

What is the status of the old Russian Emergency Control System in Ukraine? Is it still functioning? How is it maintained? Has it been redirected in light of the isolation of the Ukraine Power System? Are its settings still relevant for the new power flows across Ukraine? Does it need to be updated? Does it need to be set to operate in other directions? What kind, if any, of an Emergency Control System is relevant and appropriate for Ukraine today?

12 OPINIONS

During the investigations two opinions were identified about work on the LFC and associated systems (boiler firing, coal and ash handling, etc.) at the thermal plants. This section presents the two opinions.

At the engineering level, people understand the problems and the changes that would be needed. At the managerial level, differences of opinion are about whether or not it is worth doing the changes.

12.1 Do Not Work At Thermal Plants.

One opinion is that no work should be done at the thermal power plants, particularly the coal fired power plants, to improve the operation of the LFC and associated equipment (secondary control), and to involve the plants in automatic on-line economic dispatch (tertiary control).

It was stated that the generating units could not respond to raise / lower requests from the National Dispatch Center. Also, if they were modified to respond, the cost and effort would not be justified.

This opinion was expressed by some people at the offices in Kiev.

12.2 Do Work At Thermal Plants.

The other opinion is that it is worth while to do work at the thermal plants, particularly the coal fired plants, to improve the contribution of the plants to the performance of the primary, secondary and tertiary control loops. Such work would involve restoring or replacing the governors, installing on-line automatic LFC equipment in communication with the National Dispatch Center, and interconnecting various systems (boiler firing, coal and ash handling, feed water pumps, etc.) so that the plants responds to the raise and lower commands over as wide a range as possible.

Limit setters would also be installed between the plant systems and the automatic LFC equipment so that the plant systems would never be requested to respond beyond their limits (upper and lower regulation limits, and rate of change limits).

At all times the plant management would have the final word on what the upper and lower limits of regulation are; the automatic system from the National Dispatch Center could not override the limits set by the plants (but the system would transmit the limits to the National Dispatch Center so that the National Dispatch Center personnel and computers are aware of the limits in real-time.

This opinion was expressed by many people at the Zaporozhye thermal power plant. They understand the system, saw how it could be integrated into their plant, and understood the role of the limit setters.

They went on to say that the dead band on the governors of the 800 MW was very broad (about + / - 50 MW), could be improved, that the units could respond to LFC if the request was limited to + /- 50 MWH range. Also, long time load following could be done, provided that the rate of change of 6 MW per minute was adhered to. This rate of change limit is a reasonable request, and is a requirement common to all thermal plants.

The field personnel also pointed out that they now participate in load following over a long (say, 6 hour) period, and do this by telephone conversations with the National Dispatch Center.

What is proposed in this option is to automate and place on-line in real time, what is done now manually by telephone.

12.3 Recommendation.

This report recommends that second option, that is, doing some work on the LFC and associated systems (boiler firing, coal and ash handling, etc.) at the thermal plants.

The foundations of this recommendation are:

1. Other utilities, with extensive use of coal fired thermal plants, have the plants participating in primary, secondary and tertiary control. The experience is positive.

   It is pointed out, though, that for these companies the plants were designed to participate in such control. For Ukraine, modifications to the plants may be necessary since the plants were not designed by the Russians to operated in this manner.

2. In many other countries improvements in systems (utilities, manufacturing, society, etc.) are implemented piece by piece, one day at a time.

   The quality of other countries products and services (for example Japan and Europe) is testimony to the principle of continual improvement. This philosophy of continual improvement is recommended for the LFC and Economic Dispatch problem studied in this report.

3. As shown in Table 4.1.b, page 13, attaining the 4 percent guideline of the UCPTE for capacity participating in secondary control is expected to come from the thermal plants. The sooner the thermal plants are contributing to secondary control, the sooner the Ukrainian power system can reconnect with the neighboring power systems.

ANNEX 1
DEVELOPMENT OF COST ESTIMATES

This Annex contains the details of the development of the cost estimates for the various projects.

So as to provide The World Bank with confident cost estimates, the following projects were defined. The details (assumptions, costs, material and labor, extent of implementation, alternatives for future enhancements, etc.) of the Projects are presented in this Annex.

Variations on these Projects are possible. The Ukraine power system engineers, in conjunction with The World Bank, will develop the technical and commercial specifications for International Competitive Bidding (ICB). It is those specifications, and not this report, that will define what systems Ukraine ultimately purchases.

All functions, equipment and costs used in the report are based upon experience, and are allocated in this report based upon two weeks investigations in Ukraine.

Subsequent analysis by others will produce more accurate numbers. International competitive bidding under The World Bank procedures will identify the true market price of these systems and equipment.

By presenting the methodology of cost development in this Annex, the reader will be able to adjust the costs based upon their experience, understanding of the projects, and different definitions of the projects.

Where appropriate, software costs are identified.

On some procurement The World Bank may require the foreign bidder to assume responsibility for acceptance of locally procured (not World Bank financed) components, and for supervision of installation of these locally - procured items and components. The foreign supplier would, of course, include the cost of quality control and installation supervision in the bid.

The total estimated cost of the project is the combination (sum) of the Estimated Foreign Exchange Cost and the Estimated Local (Ukraine) Cost.

Est. FE Cost – Estimated Foreign Exchange Cost.

This cost is the estimated international cost of the item. This cost is expressed in US Dollars. The cost includes the purchase price and the cost of the supplier to install, start up, and test the device at the work site in the Ukraine.

Est. Local Cost – Estimated Local Cost

This cost is composed of two components. This cost is expressed in US Dollars.

a. The estimated cost of the item or service manufactured in Ukraine and bought in Ukraine.
b. The estimated cost of Ukrainian labor required to install, start up, and test the new system.

A1.1 Projects 1 & 2: Restore LFC and Associated Equipment At Plants.

Restore or replace the governor, load - frequency control and associated equipment at hydro plants and thermal generating plants (coal, oil and gas) identified further in this Section. This work includes the reconstruction or replacement of governors, and such new equipment as instrumentation, power transducers, energy meters, telemechanical (telemeasure, telesignal and telecontrol) equipment, limit and rate of change setters, and communications equipment.

This project directly benefits the primary control of the power system and significantly contributes to the secondary and tertiary control of the power system.

Estimated Cost Per Generating Unit, Where New Governors are Installed.

Item	Description	Est. FE Cost (x1,000)	Est. Local Cost (x1,000)
1.	Governor system (hydraulic, mechanical, & electronics)	100	
2.	Instrumentation, limit setters for data acq. and control	7	
3.	Power (MW and Mvar) transducers	3	
4.	Energy (MWH) meters	3	
5.	Telemechanical equipment	4	
6.	Communications equipment	5	
7.	Miscellaneous parts (wire, steel, etc.)	8	(included)
8.	Labor install	(included)	40
	Total	130	40

The estimated cost of the governor system includes the specialty hydraulics, the mechanical system, and the electronics. Not included in this estimate are the costs of such items as the hydraulic pumps, pressure (accumulator) tanks, valving and piping, etc. These later costs are assumed to be already included in the hydro rehabilitation project costs.

The same cost estimate is used for both hydro and thermal generating units.

A1.1 Project 1: Restore LFC and Associated Equipment At Hydro Plants.
(Continued)

The labor to install the equipment used in the above calculation was estimated as follows:

Estimated allocation of Labor (the actual work will occur over many months):

Activity	People (number)	Duration (weeks)	Effort (man - months)
Engineering and Design	4	10	10
Preparation of Drawings	4	10	10
Purchase and Receive Material.	2	20	10
Remove Existing Equipment.	20	2	10
Installation.	20	2	10
Start up and Debug.	20	2	10
Testing and Acceptance.	20	2	10
Contingency			30
Total			100

These are average allocations of labor. It is expected that more labor will be needed for the initial units worked on, but labor will decrease after experience is gained and systematic procedures applicable to all units are developed.

The estimated average daily rate is $400 per person per month.

It is assumed that the unit will be converted during a scheduled outage, hence there is no additional project cost associated with removing the unit from service. It is assumed that the crew will work six day weeks to return the unit to service (that is, 27 (31-4) work days per month.

It is assumed that are no environmental problems with this work (for example, asbestos removal, or PCB clean up).

Equipment may be either restored or replaced, which ever is most economic. The same cost estimate is used for both restoration and replacement.

In this project all instrumentation, transducers, meters, and associate wiring are upgraded. It is assumed that Projects 1 and 2 precede Project 3 (where remote terminal units and new communications technology is implemented).

A1.1 Project 1: Restore LFC and Associated Equipment At Hydro Plants.
(Continued)

Number of Hydro Generating Units Where Governor and Related LFC Systems Will Be Worked On:

Project 1: Hydro Plants (per SGI list):	Sets of LFC and Associated Equipment
Dneprovskaya Hydro No. 1	9
Dneprovskaya Hydro No. 2	---. (no work planned)
Dneprodzerhinsk Hydro	8
Kakhovka Hydro	6
Kanev Hydro	24
Kiev Hydro	20
Kiev Pumped Storage	---. (no work planned)
Kremenchug Hydro	12
Total	79. (over 5 years)

Estimated Cost (hydro generating units), Project 1.

Estimated Foreign Exchange Cost	$ 10.270 million;
Estimated Local Cost	$ 3.160 million; and,
Total	$ 13.430 million.

The cost of the rehabilitation of the governor systems of the hydro plants is estimated above so that the magnitude of the work can be understood and evaluated. The actual work and costing is included in the Hydro Rehabilitation project managed by the Hydro Department of Minenergo.

A1.2 Project 2: Restore LFC and Associated Equipment At Thermal Plants.

Project 2: Thermal Plants	Sets of LFC and Associated Equipment
Zaporozhye	7
Uglegorsk	7
Krivoy Rog No. 2	10
Zmiev	16
Burshtynskaya	12
Pridneprovskaya	8
Luganska	10
Starobeshevsk	10
Slaviansk	4
Ladyzhinskaya	6
Tripolskaya	6
Kurachovskaya	7
Zuev - 2	7
Kiev-5 heat and power generating	4
Kiev-6 heat and power generating	2
Total	116

Assume the LFC and associated equipment in 63 of the 116 units (54.3 percent) are restored in 5 years.

Estimated Cost (thermal generating units), Project 2.

Estimated Foreign Exchange Cost	$ 8.190 million;
Estimated Local Cost	$ 2.520 million; and,
Total	$ 10.710 million.

Estimated Cost (all hydro and thermal generating units), Project 1 & 2.

Estimated Foreign Exchange Cost	$ 18.460 million;
Estimated Local Cost	$ 5.680 million; and,
Total	$ 24.140 million.

Comments:

Since many nearly identical governors will be used for this project, a Ukraine company such as Turboatom in Kharkov, or an institute, may be able to develop the new governors to meet the technical specifications. This would help to increase the local content of the project and decrease the foreign exchange component.

A1.3 Project 3: Data Acquisition and Control For Plants.

Improve the telemeasure, telesignal and telecontrol information to and from all generating plants (hydro, thermal, and nuclear). The new system should include the following:

new technology to handle generator raise / lower commands,
monitoring unit status (off line, on-line-manual, on-line-automatic, tripped),
type of fuel burned (if gas or mazut),
upper and lower limits as set by the plant operator,
collection of hourly MWH readings,
interface of raise / lower commands to unit control system,
remote terminal unit (RTU), and
associated communications equipment and channel.

The installation of limit and rate of change setters occurs in Projects 1 and 2, when the unit is down for extensive rework of its control system.

Though the present telemechanical system may handle most of this additional information, the new control center Project 3 makes the handling of this data in the new Dispatch Center possible.

It is assumed that Projects 1 and 2 precede and are completed before Project 3. In Projects 1 and 2 the instrumentation, transducers, meters, and associated wiring was upgraded. The cost of this instrumentation, transducers and meters is not included in Project 3.

Projects 1, 2, 3, 4, 5 and 6 need to be coordinated so that duplicate work is not done, or that necessary upgrades are missed.

Estimated Cost of Improving Telemechanical Per Remote Terminal Unit.

Item	Description	Est. FE Cost (x1,000)	Est. Local Cost (x1,000)
1.	RTUs (handles 2 to 3 generating units each)	5	
2.	Instrumentation (in excess of Projects 1 and 2)	4	
3.	Communications equipment	5	
4.	Miscellaneous parts (wire, steel, etc.)	4	(included)
5.	Labor install (see below)	(included)	5.200
	Total	18	5.200

A1.3 Project 3: Data Acquisition and Control For Plants.
(Continued)

The estimated labor to install the equipment is calculated below.

Estimated allocation of labor per generating unit (the actual work will be spread over many months):

Activity	People (number)	Duration (weeks)	Effort (man - months)
Engineering and Design	2	4	2
Preparation of Drawings.	3	4	3
Purchase and Receive Material.	2	2	1
Removal of Old Equipment.	4	1	1
Installation of New Equipment.	4	2	2
Start up and Debug.	4	1	1
Testing and Acceptance	4	1	1
Contingency			2
Total			13

These are average allocations of labor. It is expected that more labor will be needed for the initial units worked on, but labor will decrease after experience is gained and systematic procedures applicable to all units are developed.

It is assumed that each remote terminal unit (RTU) will handle 2 or 3 generating units. This is considered a compromise between the heavy data loading on the communications lines if one RTU per generator was used, and the large wiring cost, increased complexity, and risk of reliability when more than 3 generating units are put on an RTU.

The validity of the 2 or 3 generating units per RTU needs to be reviewed critically so that these units are polled rapidly enough by the central computer. Adjustments to the number of RTUs in the project will not significantly affect the project cost or benefits.

The same estimated cost per RTU is used whether 1, 2 or 3 generating units are monitored and controlled.

The estimated average daily rate is $ 400 per person per month.

It is assumed that the unit will be converted during a scheduled outage, hence there is no additional project cost associated with removing the unit from service. It is assumed that the crew will work six day weeks to return the unit to service (that is, 27 (31-4) work days per month.

A1.3 Project 3: Data Acquisition and Control For Plants.
(Continued)

It is assumed that are no environmental problems with this work (for example, asbestos removal, or PCB clean up).

Equipment may be either restored or replaced, which ever is most economic.

In this project all instrumentation, transducers, meters, and associate wiring are upgraded. It is assumed that Projects 1 and 2 precede Project 3 (where remote terminal units and new communications technology is implemented.

A1.3 Project 3: Data Acquisition and Control for Plants.
(Continued)

Number of RTUs Planned For Each Generating Plant:

Hydro Plants:	RTUs:
Kiev Pumped Storage	3
Kiev Hydro	10. (use 4 phone lines)
Kanev Hydro	12. (use 4 phone lines)
Kremenchug Hydro	6
Dneprodzerhinsk Hydro	4
Dneprovskaya Hydro No. 1	5
Kavkovska Hydro	3
Dneprovskaya Hydro No. 2	4
Dnistrovskaya Hydro Pumped Storage	3
Total (Hydro)	50

Thermal Plants:	RTUs:
Zaporozhye	4
Uglegorsk	4
Krivoy Rog No. 2	5
Zmiev	5. (use 2 phone lines)
Burshtynskaya	6. (use 2 phone lines)
Pridneprovskaya	4
Starobeshevsk	5. (use 2 phone lines)
Slaviansk	2
Ladyzhinskaya	3
Tripolskaja	3
Luganska	5. (use 2 phone lines)
Kurachovskaya	4
Kiev-5 heat and power generating	2
Kiev-6 heat and power generating	1
Kharkivska-5 heat & power	2
Total (Thermal)	55

Nuclear Plants:	RTUs:
Zaporizka	3
Chornobylska	2
Pivdenno-Ukrainska	2
Rivnenska	2
Khmelnytska	1
Total (Nuclear)	10
Total (Hydro, Thermal, and Nuclear)	115

A1.3 Project 3: Data Acquisition and Control for Plants.
(Continued)

Estimated cost for 115 remote terminal units and associated equipment for all hydro, thermal and nuclear generating units.

Estimated Foreign Exchange Cost	$ 2.070 million;
Estimated Local Cost	$ 0.598 million; and,
Total	$ 2.668 million.

Comments:

Since many nearly identical Remote Terminal Units (RTUs) are used in this project, a Ukraine company or institute may be able to develop the new RTUs to meet the technical specifications for the above project.

A1.4 Project 4: Regional Dispatch Centers (8).

At each of the eight Regional Dispatch Centers (RDCs) work stations (computers) and associated communications equipment will be installed to monitor and report the data exchanges between the National Dispatch Center, and the generating plants and transmission stations in the Region.

At some later time, when justified, the systems at the RDCs can be expanded to full supervisory control and data acquisition capability.

Estimated Cost For Data Handling Equipment at Regional Dispatch Centers (8).
(ni - not included in project.)

Item	Description	Est. FE Cost ($ million)	Est. Local Cost ($ million)
1.	Building (site) services (res. gen., HVAC, etc.)	ni	ni
2.	Building structural and architectural changes.	ni	ni
3.	Communications equipment and channels (RDCs).	ni	0.020
4.	Computer hardware, including display CRTs.	ni	0.015
5.	Computer software for functions listed above.	(below)	ni
6.	Display Board, chart recorders, instruments.	ni	ni
7.	Regional Dispatch Centers (8) computers & software	2	0.238
8.	Regional Dispatch Centers (8) communications eqt.	2	0.239
7.	Engineering Services, Consultants, etc.	ni	ni
8.	Project Team, 4 People, 3 Years.	ni	0.576
9.	Reserve control center; reserve communication paths.	ni	ni
10.	Service lab and test equipment.	ni	0.010
11.	Training (4 man years)	(included)	0.192
	Total	4.0	1.280

The estimated average daily rate is $ 400 per person per month.

It is assumed that are no environmental problems with this work (for example, asbestos removal, or PCB clean up).

A1.5 Project 5: Inter - Enterprise Energy (MWH) Collecting and Reporting (At Key Sub-stations).

This system collects megawatt - hour (MWH) readings each hour from key metering points on the system. These readings are used to determine the inter - enterprise bills. The enterprises involved are those listed in Section 2.2, Restructuring Of the Electric Power Sector, page 3.

The likely locations are (1) transmission system connections between companies, (2) interconnections to other countries, and (3) sub stations feeds to large customers and go-generators.

The corresponding hourly readings from the power plants are collected by the Data Acquisition and Control system in Project 3.

Estimated Cost of Metering and Telemechanical to Key Stations on the Transmission and Distribution System.

Item	Description	Est. FE Cost (x1,000)	Est. Local Cost (x1,000)
1.	Remote terminal unit.	5	
2.	Circuit breaker monitoring (wiring, relays, etc.)	(included)	
3.	Power (MW and MVar) transducers.	8	
4.	Energy (MWH) meters.	8	
5.	Communications equipment and channel.	5	
7.	Miscellaneous parts (wire, steel, etc.)	2	(included)
8.	Labor install	(included)	4.4
	Total	28	4.4

Estimated allocation of labor (the actual work will be spread over many months):

Activity	People (number)	Duration (weeks)	Effort (man - months)
Engineering and Design	2	2	1
Preparation of Drawings.	2	4	2
Purchase and Receive Material.	2	2	1
Removal of Old Equipment.	4	1	1
Installation of New Equipment.	4	2	2
Start up and Debug.	4	1	1
Testing and Acceptance	4	1	1
Contingency			2
Total			11

A1.5 Project 5: Inter - Enterprise Energy (MWH) Collection and Reporting (At Key Substations).

(Continued)

These are average allocation of labor. It is expected that more labor will be needed for the initial units worked on, but labor will decrease after experience is gained and systematic procedures applicable to all units are developed.

The estimated average daily rate is $400 per person per month.

It is assumed that the RTU will be installed with having a scheduled outage, hence there is no additional project cost associated with removing the unit from service. It is assumed that the crew will work five day weeks to return the station equipment to service (that is, 20 work days per month).

It is assumed that are no environmental problems with this work (for example, asbestos removal, or PCB clean up).

It is estimated that 50 stations will have to have this system installed. It is expected that these 50 stations will be spread across all 8 Regional Dispatch Areas. The signals from these substations will be routed through the Regional Dispatch Center computers.

Cost for monitoring 50 stations for MWH Reporting, Project 5.

Estimated Foreign Exchange Cost	$ 1.400 million;
Estimated Local Cost	$ 0.220 million; and,
Total	$ 1.620 million.

A1.6 Project 6: Implement LFC and On-Line Economic Dispatch at the National Dispatch Center.

Upgrade the dispatch computer system at the National Dispatch Center. The following features are to be included in the new system:

Load - Frequency Control;
On-Line Economic Dispatch;
Supervisory Control and Data Acquisition to support LFC and On-Line Economic Dispatch;
Interconnection Scheduling and Billing;
Inter - Enterprise Energy (MWH) Collection and Reporting;
Generation Bidding and Forecasting (special, see note below);

This work will involve new computer hardware and software, CRTs, communications equipment, and training.

The emphasis is the system is on economic dispatch of the hydro and thermal generating units so as to support LFC and the reduce fuel costs. Supervisory control and data acquisition, state estimation, contingency analysis, water use optimization, logging and reporting or transmission switching operations, optimal power flow, and display board driving is not part of the basic system proposed in this project. They could be, though, added later.

This system is designed to be modular, based on RISC 6000 / Besta / Sun type of work stations, operating on a local area network (LAN), with an open software architecture such as Unix. Additional work stations and functions can be added to the network when justified and implemented.

Personal computers (PCs) were considered for the project, but were not recommended because of the high volume of data and time criticality of the real time data processing for LFC and On-Line Economic Dispatch. Furthermore, the work stations provide a more solid basis upon which to built future dispatch center growth than PCs. At the time of the bidding the bidders will reveal much about the merits of work station versus PC for this project.

The Generation Bidding and Forecasting Function will be a special function developed for the Ukraine power system. It should fit in well with the standard energy management system (EMS) that they will obtain. By being part of the EMS, the new bidding and forecasting function will be smoothly integrated into the National Dispatch Center operation.

The cost of the training of the National Dispatch Center personnel is to be included by the bidder in the basic bid. Training should be spread out over a one year period so that the attendees get maximum benefits of the material.

A1.6 Project 6: Implement LFC and On-Line Economic Dispatch At the National Dispatch Center.

(Continued)

Estimated Cost to Upgrade National Dispatch Center.
(ni - not included in project.)

Item	Description	Est. FE Cost ($ million)	Est. Local Cost ($ million)
1.	Building (site) services (res. gen., HVAC, etc.)	ni	ni
2.	Building structural and architectural changes.	ni	ni
3.	Communications equipment and channels (RDCs).	0.7	0.040
4.	Computer hardware, including display CRTs.	1	0.010
5.	Computer software for functions listed above.	1.6	ni
6.	Display Board, chart recorders, instruments.	ni	ni
7.	Regional Dispatch Centers (8) computers & software	ni	ni
8	Regional Dispatch Centers (8) communications eqt.	ni	ni
9.	Engineering Services, Consultants, etc.	0.3	ni
10	Project Team, 4 People, 3 Years.	ni	1.152
11	Reserve control center; reserve communication paths.	ni	ni
12.	Service lab and test equipment.	0.3	0.020
13.	Training (4 man years)	(included)	0.384
	Total	3.9	1.606

A1.7 Summary of Project Cost Estimates.

Project Number	Component		FE Cost (million)	Local Cost (million)	Total Cost (million)
1	LFC Equipment at Hydro Plants.		10.270	3.160	13.430
2	LFC Equipment at Thermal Plants.		8.190	2.520	10.710
	Total, Hydro and Thermal Plants.		18.460	5.680	24.140
3	Data Acquisition and Control For Plants.		2.070	0.598	2.668
4	Regional Dispatch Centers (8).		4.000	1.280	5.280
5	Inter - Enterprise Energy (MWH) Data Collection and Reporting.		1.400	0.220	1.620
6	LFC and On-Line Economic Dispatch for National Dispatch Center.		3.900	1.606	5.506
	Total (Including LFC Equipment at Hydro Plants).		29.830	9.384	39.214
	Total (Excluding LFC Equipment at Hydro Plants).		19.560	6.224	25.784

Table A1.7.a Project Cost Estimates. The total cost <u>including</u> the LFC and associated equipment at the hydro plants is an appropriate number to use when evaluating the costs and the benefits of improving on-line economic dispatch, and frequency and time regulation.

The total cost <u>excluding</u> LFC and associated equipment at the hydro plants is an appropriate number to use when evaluating the costs of projects related to the National Dispatch Center; in this case, the cost of the LFC and associated equipment at the hydro plants is included in the Hydro Rehabilitation Project.

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A1.7 Summary of Project Cost Estimates (Continued).

Project Number	Component		FE Cost (million)	Local Cost (million)	Total Cost (million)
	Upgrade of Governors and Associated LFC Equipment.				
1	Load - Frequency Control Equipment At Hydro Plants.		10.270	3.160	13.430
2	Load - Frequency Control Equipment Thermal Plants.		8.190	2.520	10.710
	Subtotal (excluding Hydro, which is in Rehabilitation Project).		8.190	2.520	10.710
	Communications and Data Acquisition Systems.				
3	Data Acquisition and Control To and From the Plants.		2.070	0.598	2.668
5	Inter - Enterprise Energy (MWH) Collection and Reporting System.		1.400	0.220	1.620
	Subtotal.		3.470	0.818	4.288
	Dispatch Centers.				
4	Data Monitoring and Presentation at Regional Dispatch Centers (8).		4.000	1.280	5.280
6	Upgrade National Dispatch Center.		3.900	1.606	5.506
	Subtotal.		7.900	2.886	10.786
	Total		19.560	6.224	25.784

Table A1.7.b Project Cost Estimates. In the Aide - Memoire of the July, 1994 mission, the project costs are grouped into the three categories shown above.

[For Annex 2 of Aide - Memoire.]

ANNEX 2
UKRAINE
DISPATCH AND SYSTEM CONTROL

This annex provides more information about the control, communication and dispatch system than the Executive Summary, but with less detail than is contained in the body of the report.

When the Ukraine and Russian power systems were dispatched as one, the resources were not uniformly distributed between the two regions. The integrated operation of the two power systems never gave rise the problems that occur in Ukrainian Power System (UPS) today.

A2.1 Current Status.

A2.1.1 Frequency, Time, and Interconnection Flows.

After independence, though the UPS inherited acceptable installed capacity, the UPS is deficient in capacity that can be dedicated to frequency and time regulation. When the UPS was part of the unified power system of the former Soviet Union (FSU), frequency was regulated from large power plants on the Volga River. Moreover, time regulation was not required of the FSU system; however, it is required for participation in the UCPTE.

Although they are interconnected, the Ukrainian and Russian power systems are currently operated independently. The lack of capacity load and frequency control in Ukraine manifest itself as poor frequency regulation and large power swings on the interconnections with neighboring utilities. In November 1993, all the interconnections with the neighboring power systems were opened, except for one interconnection to part of Bulgaria. Now, the North Caucasus region of the Russia Federation is supplied by Ukraine; and in exchange, the eastern section of Ukraine is supplied by Russia. Part of the Western Ukraine is disconnected from the rest of the country, and is connected to the Central European system to maintain export sales of electricity.

There are important benefits for being interconnected with neighboring power systems. Electric energy can be exported as a commodity. Spinning reserves can be reduced since all members of the interconnected system contribute to maintaining frequency and time, especially in emergencies. The technical requirements to interconnect with the neighboring power systems, particularly the UCPTE, are the following.

(i) Enough capacity (MW) needs to be available that can directly contribute to frequency and time regulation;
(ii) The equipment for frequency regulation, and the correction of time error, should meet a set of standards that Ukraine is unable to meet today;
(iii) Power flows in the interconnection lines needs to be controlled.

Ukraine needs more MW capacity contributing to frequency regulation. The primary (fast) regulation is performed by the hydro units. The secondary regulation is performed by the load - frequency control equipment of the National Dispatch Center. This secondary loop is not operating at this time; rather, frequency is regulated manually at the Dneprovskaya Hydro plant. The tertiary loop, on-line economic dispatch, is not employed.

Communication channels between the control centers, the power plants, an the substations have limited data transfer rates. The equipment is an older technology, where and the lines are heavily utilized with data and voice combined on the same channel.

A2.1.2 New Structure of the Electric Power Sector.

When the upcoming restructuring of the power sector occurs, there is an immediate need to meter and bill the companies participating in the system. The metering and billing occurs on a hourly basis, and daily reports are needed. An on - line data system will be needed to collect the information at the National Dispatch center. Generation plants, co-generators, and large customers to submit each day their price curve and availability schedule for the next day's operation. The information needs to be collected quickly, accurately, and reliably. Similarly, the results of the bidding need to be conveyed to the bidders by the National Dispatch Center as soon as possible.

A2.2 Proposed Upgrade Measures.

A number of measures have been identified to improve system control, dispatch and communications.

(i) Upgrading of generating unit governor at thermal and hydro plants;

(ii) Upgrading of communications and data acquisition (telemechanical) systems; and,

(iii) Upgrading the National Control Center to implement load and frequency control (LFC) and on-line economic dispatch, and partial upgrade of the eight Regional Dispatch Centers.

Six projects have been identified to implement the above measures.

1. Restoration of LFC equipment at hydro plants;
2. Restoration of LFC equipment at thermal generating plants (coal, oil and gas);
3. Data acquisition and control equipment for plants;
4. Data presentation and routing computers for Regional Dispatch Centers (8);
5. Inter - Enterprise Energy (MWH) Collection and Reporting (from key sub-stations; and,
6. Implement LFC and On-Line Economic Dispatch by upgrading the computer system at the National Dispatch Center.

The existing LFC control and the associated equipment at the hydro and thermal power plants needs to be restored (or replaced) so that their original performance is returned.

The monitoring of signals from all hydro, thermal and nuclear power plants needs to be improved so that the National Dispatch Center has immediate knowledge of the status of every generating unit, type of fuel being burned (for example, gas or mazut), the upper and lower regulation limits set by the plant operator; and, so that the National Control Center can immediately send appropriate raise / lower generation commands to those units participating in LFC.

At the Regional Dispatch Centers, communication equipment and computers will be installed which will collect and present the information about MWH reporting, and generation control.

At key stations in the transmission system, metering and data collection equipment will be installed to support the inter - enterprise megawatt-hour (MWH) billing in the newly structured electric power sector.

The computer system of the National Dispatch Center should be replaced. Four very important and very useful functions need to be added: load - frequency control, on-line economic dispatch, bidding and scheduling of generation by the generating companies, and inter - enterprise billing.

The existing computers are old, maintenance is a concern, and these four new functions cannot be installed in them.

The communication channels are generally good; however, the terminal equipment at each end of the lines should be upgraded. This will increase the data rates, while retaining the existing data channels through the cables and through the telephone company.

The upgrade National Dispatch Center, supported by the restored governors and associated equipment at the hydro and thermal plants, and the rehabilitation of the hydro plants should reduce the annual fuel costs by about 1.9 percent annually. Assuming about half (63 of 119) of the thermal generating units have their governors and associated equipment restored or replaced, annual fuel costs savings could amount to about US $39.3 million, indicating that the proposed system control projects would be economically very attractive.

The cost (foreign exchange plus local) of the six projects is $ 19.56 million. The payback occurs in about 6 months.

With such a rapid pay back, and since the project directly contributes to the national goal of reducing imported oil and gas, all six projects should proceed immediately.

A2.3 Related Projects.

Three related projects will significantly contribute to the improvement in system control. They are:

1. Hydro plant rehabilitation;
2. Completion of Dnestrovkaya Hydro Pumped Storage Facility; and,
3. Study of the coal supply to the thermal plants should recommend improvements in the quality (kcal per kilogram, and ash) and consistency (uniformity of characteristics from batch to batch).

A2.4 Coordination of Work.

The mission understands that other companies, including equipment suppliers (Landis & Gyr, Switzerland), and foreign utilities (Electricite de France, France) are also involved in the work to modernize system control and dispatch in Ukraine. Minenergo has to ensure that the various activities are properly coordinated ensuring proper phasing, consistency and avoiding conflicts and overlap.

ANNEX 3
BILLING IN INTERCONNECTED POWER SYSTEM OPERATION

Traditional electro-mechanical and modern electronic watthour meters are used in the billing of interconnected power systems. There is, though, a major difference in how the meter readings are used to generate the bills when compared to residential, commercial and industrial billing.

A3.1 Customers Or Generators Connected Radially.

For those customers (retail, commercial, and industrial) that are fed radially, and for those generating plant that correspondingly supply their generation to the transmission system through one MWH meter, the meter reading on that line or generator is the customer's bill or credit.

A3.2 Customers Or Generators Connected By a Network.

However, for customers, companies, electric utilities, and interconnected power systems connected by multiple transmission lines the billing is different (but correspondingly simple).

For these network connected customers and loads, their bill is the sum of all of the energy that they receive, less that energy that passes (wheels) through their utility (or generating facility). Furthermore, for these system members the assignment of responsibility for losses in the transmission system may be a part of their tariff or contract.

Hence, the method of generating bills and credits for members of an interconnected power system is different than for radially connected customers.

In interconnected power system operation the Inter - Enterprise Energy (MWH) Collection and Reporting (IEECR) system works in conjunction with the load - frequency control (LFC) function. The IEECR provides the LFC function (usually each hour) with a number (one number per LFC Region or company being controlled) about how much to adjust the scheduled generation up (or down) for the next hour. This adjustment is made to "pay back" a bookkeeping entry called the "hourly inadvertent". In this way the IEECR, working through the LFC, works to minimize the mismatch between planned and actual energy sale contracts.

The IEECR and LFC work together to keep the "inadvertent accounts" near zero, and thus satisfy the contracts for interconnection and inter - enterprise electricity sales.

"Inadvertent accounts" are traditionally paid back "in time and in kind." That is, if one company took 10 MWH more from the system than it should have between 2 and 3 PM on a given day, that company must export 10 MWH between 2 and 3 PM the next day. Or, depending on the rules of the power system, the pay back may occur the same day the next week, or the same day a month later. It is not appropriate to pay back at night for inadvertent energy used during the day.

The number of "inadvertent accounts" in the billing system is easy to estimate. Holidays can be treated as weekends.

Time Period For "In Time and In Kind" Payback.	Number of "Inadvertent Account" Entries	Comment.
Daily	48	24 weekday hours plus 24 weekend hours.
Weekly	168	24 hours per day times 7 days per week.
Monthly	744	24 hours per day times 31 days per month.

The IEECR calculates the "inadvertent accounts" (one account for each LFC Region (member) being controlled and dispatched each hour. The inputs for this calculation are the data acquisition system from the power plants, and the MWH meters at key metering points on the transmission network.

Under the above scenario, since the "inadvertent accounts" are near zero, and since there is confidence and trust that the non-zero balances in the accounts will be paid back by the members of the system "in time and in kind" within, say, a month, the IEECR can compute the bills between the member companies and interconnections of the system based solely on the contracts. The actual meter readings are not necessary to produce the bills.

So, the MWH meters at a particular station do not directly contribute to the bills of the member companies, but with out so much as one of the readings, the balancing of the "inadvertent accounts" cannot occur. If a meter reading is absent, the Dispatch Center works to obtain the reading.

ANNEX 4
LIMITS OF GENERATING UNIT REGULATION

The Tables in this Annex are for recording the present, planned and 'actual-after-rehabilitation' ranges of capacity (MW) participating in load - frequency control (secondary control loop).

The list of plants is taken from Sections 13 and 14 of "Power Industry of Ukraine."[7]

The range is the extent (that is, high limit minus low limit, expressed in MW) over which the generating unit can be moved in a few minutes. The range usually a relatively narrow band for a thermal generating unit, say, + / - 50 MW for a 800 MW unit. The range in this example is, thus, 100 MW.

The range is usually a relatively large band for a hydro generating unit, say 10 MW to 50 MW for a 58 MW unit. The range for this example is 40 MW.

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[7] "Power Industry of Ukraine," by The Ministry of Power and Electrification of Ukraine, published in Kiev in 1994. Same as Footnote 1.

Annex 4 Limits of Generating Unit Regulation (Continued).

Plant	Number of Units	Capacity (MW)	Present Range of a Unit (MW)	Planned Range of a Unit (MW)	Range of a Unit After Rehab. (MW)
Zaporozhye	3	800			
	4	300			
Uglegorsk	3	800			
	4	300			
Krivoy Rog No. 2	10	282			
Burshtynskaya	8	195			
	4	185			
Zmiev	4	275			
	6	175			
Starobeshevsk	10	175			
Ladyzhinskaya	6	300			
Pridneprovskaya	4	285			
	4	150			
Tripolskaya	6	300			
Luganska	8	175			
	2	100			

Table A4.a Limits of Generating Unit Regulation For Thermal Generating Units.

Annex 4 Limits of Generating Unit Regulation (Continued).

Plant	Number of Units	Capacity (MW)	Present Range of a Unit (MW)	Planned Range of a Unit (MW)	Range of a Unit After Rehab. (MW)
Slaviansk	1	720			
	1	100			
	1	800			
	1	80			
Kurakhovskaya	6	210			
	1	200			
Kiev - 5 TPS	2	250			
	2	100			
Kiev - 6 TPS	2	250			
Kharkivska TPS - 5	1	250			

Table A4.a Limits of Generating Unit Regulation For Thermal Generating Units (Continued).

Annex 4 Limits of Generating Unit Regulation (Continued).

Plant	Number of Units	Capacity (MW)	Present Range of a Unit (MW)	Planned Range of a Unit (MW)	Range of a Unit After Rehab. (MW)
Kiev Hydro Pumped Storage	3	41.5			
	3	37.0			
Kiev Hydro	16	18.5			
	4	16.3			
Kanev Hydro	24	18.5			
Kremenchug Hydro	12	52.0			
Dneprodzerhinsk Hydro	8	44.0			
Dnestrovskaya Hydro No. 2	6	113.1			
	2	104.5			
Dnestrovskaya Hydro No. 1	9	72.0			
	1	2.6			
Kakhovka Hydro	6	58.5			
Dnestrovskaya Hydro	6	117.0			

Table A4.b Limits of Generating Unit Regulation For Hydro Generating Units.

ANNEX 5
TIME SEQUENCED INVESTMENT PLAN

This Annex contains the spread sheet that was developed to distribute the investment plan over the years of the projects. See Section 9, Investment Plan, on Page 39 for a summary table.

ANNEX 5
TIME SEQUENCED INVESTMENT PLAN FOR
CONTROL, COMMUNICATIONS AND DISPATCH PROJECTS.

Project Number	Project Description			FE Cost Estimate Dollars (Millions) 1994	Local Cost Estimate Dollars (Millions) 1994
	Load - Frequency Control Equipment At Generating Units.				
1		Hydro Plants.		10.270	3.160
2		Thermal Plants.		8.190	2.520
			Total	18.460	5.680
	Data, Communications and Control.				
3		Data Acquisition and Control For Plants.		2.070	0.598
4		Regional Dispatch Centers (8).		4.000	1.280
5		Inter - Enterprise Energy (MWH) Collection and Reporting.		1.400	0.220
6		National Dispatch Center.		3.900	1.606
			Total	11.370	3.704
		Total (Including LFC Equipment at Hydro Plants.)		29.830	9.384
		Total (Excluding LFC Equipment at Hydro Plants).		19.560	6.224
Notes:		1. Total project cost is the sum of the Foreign Exchange (FE) AND the Local Costs.			
		2. Both FE and Local costs are expressed in 1994 Dollars.			
Keys to understanding this spread sheet.					
	1.	All the answers are summarized on Page 2.			
	2.	Pages 1 contains the project names and cost estimates.			
		Edit Page 1 to affect project costs.			
	3.	Pages 3 contains the per unit allocation of the costs across the years.			
		Edit Page 3 to affect when the expenses are planned to occur.			
	4.	Pages 2 contains the matrix products of			
		(project costs) times (per unit yearly allocations).			
		Examine this page to see how the expenses occur in a given year.			

ANNEX 5
TIME SEQUENCED INVESTMENT PLAN FOR
CONTROL, COMMUNICATIONS AND DISPATCH PROJECTS.

Project Number	1995 FE $ Mil 1994	1995 Local $ Mil. 1994	1996 FE $ Mil 1994	1996 Local $ Mil. 1994	1997 FE $ Mil 1994	1997 Local $ Mil. 1994	1998 FE $ Mil 1994	1998 Local $ Mil. 1994	1999 FE $ Mil 1994	1999 Local $ Mil. 1994	2000 FE $ Mil 1994	2000 Local $ Mil. 1994	2001 FE $ Mil 1994	2001 Local $ Mil. 1994	2002 FE $ Mil 1994	2002 Local $ Mil. 1994	2003 FE $ Mil 1994	2003 Local $ Mil. 1994	Total FE $ Mil 1994	Total Local $ Mil. 1994
Load - Frequency Control Equipment At Generating Units.																				
1	1.027	0.316	2.054	0.632	2.054	0.632	2.054	0.632	2.054	0.632	1.027	0.316	0.000	0.000	0.000	0.000	0.000	0.000	10.270	3.160
2	0.819	0.252	1.638	0.504	1.638	0.504	1.638	0.504	1.638	0.504	0.819	0.252	0.000	0.000	0.000	0.000	0.000	0.000	8.190	2.520
Total	1.846	0.568	3.692	1.136	3.692	1.136	3.692	1.136	3.692	1.136	1.846	0.568	0.000	0.000	0.000	0.000	0.000	0.000	18.460	5.680
																			18.460	5.680
Data, Com	Data, Communications and Control.																			
3	0.414	0.120	0.621	0.179	0.621	0.179	0.414	0.120	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.070	0.598
4	0.400	0.128	0.800	0.256	1.200	0.384	0.800	0.256	0.800	0.256	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	4.000	1.280
5	0.280	0.044	0.420	0.066	0.420	0.066	0.280	0.044	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.400	0.220
6	0.780	0.321	1.170	0.482	1.170	0.482	0.780	0.321	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.900	1.606
Total	1.874	0.613	3.011	0.983	3.411	1.111	2.274	0.741	0.800	0.256	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	11.370	3.704
																			11.370	3.704
Total w / Hydro	3.720	1.181	6.703	2.119	7.103	2.247	5.966	1.877	4.492	1.392	1.846	0.568	0.000	0.000	0.000	0.000	0.000	0.000	29.830	9.384
																			29.830	9.384
Total w/o Hydro	2.693	0.865	4.649	1.487	5.049	1.615	3.912	1.245	2.438	0.760	0.819	0.252	0.000	0.000	0.000	0.000	0.000	0.000	19.560	6.224
																			19.560	6.224

Notes:

1. The priority and duration of projects above are preliminary, and can be changed.
2. Vertical and horizontal summations are used to confirm accuracy of formulae.
3. Both the Foreign Exchange (FE) and the Local costs are expressed in 1994 Dollars.
4. The above tables show EXPECTED CASH FLOW. The actual ACTIVITY on the project may be otherwise.
5. Total project costs are the sums of the Foreign Exchange AND the Local costs.
6. All projects are planned to be completed and operational by the end of 1999.
7. Projects are assumed to start 1 July 1995.
8. See Table 4.1.b for the hydro and thermal capacity that be available for LFC regulation.
9. The National Dispatch Center is scheduled to be operational ahead of the Regional Dispatch Centers.
10. The Inter - Enterprise Energy (MWH) Collection and Reporting System needs to be operational as soon as possible, but is paced by the work at the National Dispatch Center.
11. The work for the Data Acquisition and Control system for the Plants is paced by the work at the National Dispatch Center.
12. The "Total w/o Hydro" is the cost of this project; the governor work at hydro plants is already included in the Hydro Rehabilitation Project.

ANNEX 5
TIME SEQUENCED INVESTMENT PLAN FOR
CONTROL, COMMUNICATIONS AND DISPATCH PROJECTS.

Project Number	1995 FE Per Unit	1995 Local Per Unit	1996 FE Per Unit	1996 Local Per Unit	1997 FE Per Unit	1997 Local Per Unit	1998 FE Per Unit	1998 Local Per Unit	1999 FE Per Unit	1999 Local Per Unit	2000 FE Per Unit	2000 Local Per Unit	2001 FE Per Unit	2001 Local Per Unit	2002 FE Per Unit	2002 Local Per Unit	2003 FE Per Unit	2003 Local Per Unit	Sum (Check) FE Per Unit	Sum (Check) Local Per Unit
Load - Frequency Control Equipment At Generating Units.																				
1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1							1.0	1.0
2	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1							1.0	1.0
Data, Communications and Control.																				
3	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.2											1.0	1.0
4	0.1	0.1	0.2	0.2	0.3	0.3	0.2	0.2	0.2	0.2									1.0	1.0
5	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.2											1.0	1.0
6	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.2											1.0	1.0

This is the last page of the report.